THE ILLUSORY PERCEPTION OF MOVEMENT ON THE SKIN[1]

By ANNA KELLMAN WHITCHURCH

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The object of the present investigation was to determine the elementary conditions of the perception of cutaneous movement. Wertheimer[2] and his successors have found such conditions for the perception of movement in the field of vision; and Dimmick[3] has shown a specific existential correlate of the perception of visual movement, namely, the grey flash. Our problem, then, is to find out whether the perception of cutaneous movement can be aroused by successive stimulation, and in that case what is its existential correlate.

Benussi and others[4] have already done much work upon the arousal of cutaneous movement by successive stimuli operating at long distances apart. Benussi stimulated at distances ranging from 4 cm. to the distance between the fingers

[1] From the Psychological Laboratory of Cornell University.

[2] M. Wertheimer, Ueber das Sehen von Bewegung, *Zeit. f. Psych.*, 61, 1912, 161ff.

[3] F. L. Dimmick, An Experimental Study of Visual Movement and the Phi Phenomenon, this JOURNAL, 31, 1920, 317ff.

[4] V. Benussi, Kinematohaptische Erscheinungen, *Arch. f. d. ges. Psych.*, 29, 1913, 385; Kinematohaptische Scheinbewegung und Auffassungsumformung, *Ber. ü. d. VI Kong. f. exp. Psych.*, 1914, 31; Versuche zur Analyse taktil erweckter Scheinbewegungen, *Arch. f. d. ges. Psych.*, 36, 1916, 59. *Cf.* also H. E. Burtt, Tactual Illusions of Movement, *Jour. Exp. Psych.*, 2, 1917, 371.

on the two outstretched arms. Burtt gives reports from stimulations 8 to 16 cm. apart, and his apparatus allowed distances from 2 to 18 cm. These distances, however, favor the arousal of visual associations; and minimal distances are for that and for other reasons to be preferred. Incidental reports by von Frey and Metzner,[5] apparently overlooked by later experimenters, prove that such distances may be employed.

Von Frey and Metzner have given the only reports of work on the skin directly comparable with that of Wertheimer in vision. They were trying to find the best interval in which to distinguish as different the responses of two adjacent pressure spots successively stimulated. They used as stimuli hairs or blunt needles which rested on the skin for 1/9 sec. The intervals between stimulations were 1/9, 1/6, 1/3, 1, 4/3, and 2 sec. Near the end of their paper this statement appears: "When two points are stimulated, the difference of the two stimuli is either recognized as such, or (especially with the shorter intervals) is interpreted as a shift (*Verschiebung*) of the stimulus, as a brushing (*Streichen*) of it over the skin." The only numerical data given show that, with an interval of 4/3 second, 13 out of 29 stimulations aroused, in some form, the perception of movement.

Experimental Procedure

The present work was begun in the summer of 1920. The four *O*'s who served were: Miss C. Braddock (B), graduate scholar in psychology; Dr. K. M. Dallenbach (D), assistant professor of psychology; Dr. L. B. Hoisington (H), assistant professor of psychology; Mrs. A. K. Whitchurch (W), graduate scholar in psychology.[6]

The skin on the left fore-arm of the *O*'s was tested with von Frey hairs of various tension-values until a hair was found which could be felt upon the normal skin, but was too weak to arouse subcutaneous sensations when the skin was lightly etherized. The tension-value of the hair finally selected was 7.9 gr./mm. Two hairs were cut to this standard. They measured in length 40 and 42 mm. respectively.

Five groups of pressure-spots, ranging from 6 to 9 in number, on every *O*'s arm were isolated and stained, so that the same spots could be tested every day. During this preliminary testing one spot was stimulated only once in an hour. The stimulating hair was held 1 mm. above the pressure-spot, and

[5] M. von Frey and R. Metzner, Die Raumschwelle der Haut bei Successivreizung, *Zeit. f. Psych.*, 29 1902, 161ff.

[6] When W observed, B acted as experimenter.

after the "Ready, now" signal was touched to the spot. The *O*'s were asked to report on the intensity, quality, and extensity of the sensation. Two reports were taken when the spots were stimulated singly, and two when one spot was compared with another. The introspections were worked over, and the spots most alike were selected and again reported upon, until the first numbers chosen narrowed down to 3 or 4 in a group. Finally we were able to select two adjacent spots in every group which the *O*'s reported as like the spots in every other group. The selected spots were then permanently tattooed with a tiny glass tube just under the hair. The mark was distinct and lasting. The distances between the spots in the various groups were as follows (in mm.): B (1) 2.5, (2) 3, (3) 2.5, (4) 3, (5) 4; D (1) 5, (2) 3.6, (3) 3.2, (4) 3.8, (5) 3; H (1) 4.7, (2) 3.4, (3) 4.7, (4) 3.1, (5) 2.4; and W (1) 2.8, (2) 5.5, (3) 3.2, (4) 2.1, (5) 3.8.

Manual Experiments

O sat at a low table with his arm in a plaster cast. The adjacent hairs in the five groups were stimulated in turn. The duration of the stimulus was $250 \pm 25\sigma$. The intervals, marked by a silent pendulum, were 750, 1000, and 1250σ.

O worked under two sets of instructions. The 'process' instruction was: "I shall stimulate the skin on your arm. Describe the cutaneous perception aroused in purely psychological terms. The stimulus will be repeated so that you may complete your description." The 'meaning' instruction was: "I shall stimulate the skin on your arm. Characterize the cutaneous perception aroused, fully, in any commonsense terms you wish to use. The stimulus will be repeated so that you may complete your report."

The manual experimenting continued until every *O* had given 50 reports under the 'meaning' and 50 under the 'process' instruction with the 750 and the 1250 intervals. With the 1000 interval, every *O* made 100 reports under each set.

Results of Manual Experiments

The reports fell under headings like those which have been obtained in the work on vision: (1) full movement, in which the stimulus moved from the 1st to the 2nd spot stimulated; (2) bimembral movement, in which the 1st and 2nd stimulus each moved; (3) unimembral movement, in which either the 1st or the 2nd stimulus moved; (4) intramembral movement, in which the stimulus at one or both spots moved

within the area of stimulation; (5) pure phi, in which the movement had no qualitative, intensive, or extensive beginning and ending, but was a uniform 'brushing' over the cutaneous surface.

Table A sums up the results of this preliminary work. The columns headed M show the percentage of reports under the 'meaning' instruction; those headed P the percentage of reports under the 'process' instruction. The intervals are given in sigma.

The reports under the two instructions are closely parallel. Long before the completion of the series the *O*'s had settled into a stable manner of reporting.

The 750 interval is the best of the three for arousing the perception of full movement. Even with this interval, however, the percentages are very low. Since optimal conditions had not been found, and since the lowest interval was the best, we began a new series of experiments with shorter intervals. Henceforth we applied the stimuli by means of apparatus.

Mechanical Stimulation: Series I

The apparatus was an adaptation of Benussi's kinohapt.[7] The intervals and durations of the stimuli were controlled by a Leipsic time-sense apparatus.

Both cutaneous and 'subcutaneous'[8] stimuli were employed. The cutaneous stimuli were two horse-hairs whose tension-value was 4.85 gr./mm., and which measured in length 10 and 9.8 mm. respectively. The subcutaneous stimuli were coarser hairs whose tension-value was 10.25 gr./mm.; they measured 3 and 2.85 cm. respectively. The duration of the stimuli was 150^{σ}. The intervals of this series were 100, 250, 500, 750, and 1000^{σ}. The adjacent spots in two groups on every *O*'s arm were now stimulated exclusively.

The cutaneous (C) and subcutaneous (S) stimuli were used alternately as follows: (1) C 100, 12 M-reports on spots *a-b*, 12 P-reports on spots *a'-b'*; (2) S 250, 12 M-reports on spots *a-b*, 12 P-reports on spots *a'-b'*; (3) C 500, 12 M-reports on spots *a-b*, 12 P-reports on spots *a'-b'*; and so forth. At the end of the ten groups which this order necessitated, the experiments were continued by reversing the order. Thus after no. 10 came (11) S 100, 12 P-reports on spots *a-b*, 12 M-reports on spots *a'-b'*. The practice-effect was thus evenly

[7] For a description of the kinohapt, see V. Benussi, *Arch. f. d. ges. Psych.*, *29*, 1913, 385.

[8] We use this shorthand term to designate the stimuli which affected both cutaneous and subcutaneous end-organs.

TABLE A

MANUAL EXPERIMENTS: PERCENTAGES

		750		1000		1250	
		M	P	M	P	M	P
Full Movement	B	18	14	18	19	4	2
	D	4	4	10	16	14	2
	H	48	30	27	34	0	0
	W	14	24	23	24	2	2
	Av.	21	18	19.5	23.3	5	1.5
	M.V.	13.5	9	5.5	5.8	4.5	.8
Bimembral Movement	B	4	2	5	0	2	2
	D	0	0	0	0	0	6
	H	4	0	10	8	2	0
	W	2	10	13	15	6	10
	Av.	2.5	3	7	5.8	2.5	4.5
	M.V.	1.5	3.5	4.5	5.8	1.8	3.5
Unimembral Movement	B	12	26	9	21	42	38
	D	12	8	26	11	30	20
	H	34	54	32	34	48	42
	W	56	38	38	30	36	48
	Av.	28.5	31.5	26.3	24	39	37
	M.V.	16.5	14.5	8.8	8	6	8.5
Intramembral Movement	B	22	12	17	7	12	12
	D	14	0	3	6	0	4
	H	2	0	13	4	20	14
	W	10	6	8	6	22	6
	Av.	12	4.5	10.3	5.8	13.5	9
	M.V.	6	4.5	4.8	.9	7.5	4
Phi	B	0	2	1	1	4	0
	D	6	0	10	1	2	2
	H	2	2	0	1	0	0
	W	12	10	3	6	0	2
	Av.	5	3.5	3.5	2.3	1.5	1
	M.V.	4	3.3	3.3	1.9	1.5	1
No Movement	B	44	44	50	52	36	46
	D	64	88	51	66	54	66
	H	10	14	18	19	30	44
	W	6	12	15	19	34	32
	Av.	31	39.5	33.5	39	38.5	47
	M.V.	23	26.5	17	20	7.8	9.5

distributed. Several minutes elapsed betwen the stimulations of the same spot. At the end of every 12 reports *O* took his arm from the cast for a time, in order that there might be no fatigue. Usually *O* made reports on one group of experi-

ments in an hour, and never on more than two. Every *O* made 24 reports under the 'meaning' and 24 under the 'process' instruction for every one of the intervals employed.

Results of Series I

The results of the first series with mechanical stimulation are summarised in Tables B I and B II. The columns M and P show the number of reports of the different types of phenomena given in each group of 24 experiments.

With both cutaneous and subcutaneous stimuli the 100σ interval gives the greatest number of full movements. Next to the full movement in frequency comes the unimembral movement. The number of full movements is too small to indicate optimal conditions, and another series was accordingly planned.

The 'process' and 'meaning' reports run closely parallel, as is shown by the averages of the groups.

TABLE B—I

CUTANEOUS MECHANICAL STIMULATION: SERIES I: ABSOLUTE NUMBERS

		100		250		500		750		1000	
		M	P	M	P	M	P	M	P	M	P
Full Movement	B	9	6	3	4	0	0				
	D	8	10	3	0	0	0				
	H	6	8	7	5	1	0				
	W	13	14	0	0	0	0				
	Av.	9	9.5	3.3	2.3	.3					
	M.V.	2	2.3	1.9	2.3	.4					
Bimembral Movement	B	0	0	0	1	0	3	2	0	1	0
	D	0	0	0	0	0	0	0	0	2	2
	H	7	5	6	6	9	7	0	0	0	0
	W	8	5	5	7	8	8	2	1	0	1
	Av.	3.8	2.5	2.8	3.5	4.3	4.5	1	.3	.8	.8
	M.V.	3.8	2.5	2.8	3	4.3	3	1	.4	.8	.8
Unimembral Movement	B	5	8	6	4	10	8	5	6	4	7
	D	12	12	14	9	5	1	4	3	3	0
	H	10	11	10	11	8	9	9	10	9	8
	W	3	5	13	15	14	14	7	8	7	7
	Av.	7.5	9	10.8	9.8	9.3	8	6.3	6.8	5.8	5.5
	M.V.	3.5	2.5	2.8	3.3	2.8	3.5	1.8	2.3	2.2	2.8
Intramembral Movement	B			1		3	5	13	7	9	7
	D			5		0	0	0	0	1	1
	H			0		4	2	5	3	5	5
	W			2		0	0	3	2	3	2
	Av.			2		1.8	1.8	5.3	3	4.5	3.8
	M.V.			1.5		1.8	1.8	3.8	2	2.5	2.3
No Movement	B	9	8	14	15	11	8	4	11	10	10
	D	3	2	2	15	19	23	20	21	18	21
	H	1	0	1	2	2	6	10	11	10	11
	W	0	0	4	2	2	2	12	13	14	14
	Av.	3.3	2.5	5.3	8.5	8.5	9.8	11.5	14	13	14
	M.V.	2.9	2.8	4.8	7.7	6.6	6.6	4.5	3.5	3	3.5

With the 100 interval, B reported phi in 1 M and 2 P; D in 1 M.

TABLE B—II

SUBCUTANEOUS MECHANICAL STIMULATION: SERIES I: ABSOLUTE NUMBERS

		100		250		500		750		1000	
		M	P	M	P	M	P	M	P	M	P
Full Movement	B	10	13	2	3						
	D	14	10	18	11						
	H	15	13	7	7						
	W	15	15	11	10						
	Av.	13.5	12.8	9.5	7.8						
	M.V.	1.8	1.4	5	2.8						
Bimembral Movement	B	0	1	0	0	3	4	2	0	1	0
	D	2	3	6	8	2	0	2	0	0	0
	H	4	0	4	5	0	1	1	1	0	0
	W	4	6	3	5	6	9	4	2	0	0
	Av.	2.5	2.5	3.3	4.5	2.8	3.5	2.3	.8	.3	
	M.V.	1.5	2	1.8	2.3	1.8	3	.9	.8	.4	
Unimembral Movement	B	5	3	12	11	7	4	8	9	0	4
	D	2	4	0	1	12	20	7	6	2	0
	H	4	8	10	10	10	9	8	11	9	8
	W	5	3	10	8	9	7	13	15	7	4
	Av.	4	4.5	8	7.5	9.5	10	9	10.3	4.5	4
	M.V.	1	1.8	3.3	3.5	1.5	5	2	2.8	3.5	2
Intramembral Movement	B	0	0	0	0	2	3	6	5	3	4
	D	0	2	0	0	2	0	0	0	1	5
	H	0	0	2	1	5	8	5	4	4	5
	W	0	0	0	0	2	1	2	2	12	13
	Av.		.5	.5	.3	2.8	3	3.3	2.8	5	6.8
	M.V.		.8	.8	.8	1	2.3	2.3	1.8	3.5	3.2
No Movement	B	9	7	10	10	12	13	8	10	20	16
	D	5	5	0	4	8	4	15	18	21	19
	H	1	3	1	1	9	6	10	8	11	11
	W	0	0	0	1	7	7	5	5	5	7
	Av.	3.8	3.8	2.8	4	9	7.5	9.5	10.3	14.3	13.3
	M.V.	3.3	2.3	3.6	3	1.5	2.8	3	3.9	6.3	4.3

With the 100 interval, D reported phi in 1 M.

Series II

The intervals chosen for the next series were 25, 50, 75, and 100$^{\sigma}$. The arrangement of the groups and the procedure were as before.

The results are summarised in Tables C I and C II. The 100$^{\sigma}$ interval gives the greatest number of full movements with cutaneous stimulation, and the 75$^{\sigma}$ interval with subcutaneous stimulation. Again the 'process' and 'meaning' reports parallel each other.

A group of 24 experiments with each stimulus in each of the intervals 125 and 150$^{\sigma}$ was made as a part of this series with *O*'s H and W. Full movements were reported in the following cases: C 125, H 9M and 8P, W 8M and 6P; C 150, H 5M and 4P, W 4M and 4P; S 125, H 6M and 4P, W 5M and 3P; S 150, H 6M and 6P, W 5M and 4P.

TABLE C—I

CUTANEOUS MECHANICAL STIMULATION: SERIES II: ABSOLUTE NUMBERS

		25		50		75		100	
		M	P	M	P	M	P	M	P
Full Movement	B	0	0	19	23	17	16	14	19
	D	5	1	9	6	7	8	11	9
	H	2	6	10	4	11	11	14	15
	W	0	0	10	13	14	15	16	14
	Av.	1.8	1.8	12	11.5	12.3	12.5	13.8	14.3
	M.V.	1.8	2.1	3.5	6.5	3.3	3	1.4	2.8
Bimembral Movement	B			0	0	0	0	0	0
	D			0	0	0	0	0	0
	H			4	4	2	3	4	3
	W			2	0	4	3	4	5
	Av.			1.5	1	1.5	1.5	2	2
	M.V.			1.5	1.5	1.5	1.5	2	2
Unimembral Movement	B	1	0	0	0	0	3	2	2
	D	12	8	12	14	11	6	10	9
	H	5	5	9	11	7	7	6	6
	W	1	1	3	4	6	6	4	5
	Av.	4.8	3.5	6	7.3	6	5.5	5.5	5.5
	M.V.	3.8	3	4.5	5.3	3	1.3	2.5	2
Intramembral Movement	B	3	4	3	0	2	0	2	0
	D	0	0	0	0	0	0	0	0
	H	0	0	0	0	0	1	0	0
	W	2	0	0	0	0	0	0	0
	Av.	1.3	1	.8		.5	.3	.5	
	M.V.	1.3	1.5	1.1		.8	.4	.8	
No Movement	B	20	20	1	1	5	5	6	3
	D	7	14	2	4	6	10	3	6
	H	17	13	1	5	4	2	0	0
	W	21	23	9	7	0	0	0	0
	Av.	16.3	17.5	3.3	4.3	3.8	4.3	2.3	2.3
	M.V.	4.3	4	2.9	1.8	1.9	3.3	2.3	2.3

With the 25 interval, D reported phi in 1 P; with the 50 interval, B reported it in 1 M, and D in 1 M.

Types of Perception

The reports arising from the cutaneous and subcutaneous stimulations are so nearly alike that we shall for the most part confine our discussion to the former and shall mention the 'subcutaneous' reports only where differences occur. The reports under the 'meaning' and 'process' instructions will not be treated separately. They will be grouped together in the following discussions, and throughout 'meaning' will be dealt with first.

(1) *Full Movement.*—In all cases of full movement, the stimuli are felt as two touches with movement between them from *a* to *b*. The type appearing most often is that of the dumb-bell pattern. The stimulus touches, lifts, and moves in a narrow line to a new position. In 'process' the first impression is a round or oval bit of extent. The impression

TABLE C—II

SUBCUTANEOUS MECHANICAL STIMULATION: SERIES II: ABSOLUTE NUMBERS

		25		50		75		100	
		M	P	M	P	M	P	M	P
Full Movement	B	1	5	5	2	11	14	15	17
	D	7	6	6	1	18	12	11	15
	H	0	0	3	3	16	15	10	10
	W	0	0	2	0	19	18	17	15
	Av.	2	2.8	4	1.5	16	14.8	13.3	14.3
	M.V.	2.5	2.8	1.5	1	2.5	1.8	2.5	2.1
Bimembral Movement	B			0	0	0	0	0	0
	D			0	0	0	0	0	0
	H			0	2	0	2	3	1
	W			0	0	1	2	1	0
	Av.				.5	.3	1	1	.3
	M.V.				.8	.4	1	1	.4
Unimembral Movement	B	0	0	1	6	1	5	0	0
	D	11	13	16	21	0	0	9	2
	H	2	1	9	9	6	7	11	13
	W	4	2	4	4	4	4	6	9
	Av.	4.3	4	7.5	10	2.8	4	6.5	6
	M.V.	3.8	4.5	5	5.5	2.3	2	3.5	5
Intramembral Movement	B	7	0	2	3	2	1	1	2
	D	0	0	0	0	1	0	0	0
	H	0	1	3	1	0	0	0	0
	W	0	0	0	0	0	0	0	0
	Av.	1.8	.3	1.3	1	.8	.3	.3	.5
	M.V.	2.6	.4	1.3	1	.8	.4	.4	.8
No Movement	B	16	19	16	13	10	4	8	5
	D	6	5	2	2	5	12	3	7
	H	22	22	9	9	2	0	0	0
	W	20	22	18	20	0	0	0	0
	Av.	16	17	11.3	11	4.3	4	2.8	3
	M.V.	5	6	5.8	5.5	3.3	4	3.9	3

With the 100 interval, D reported phi in 1 M.

extends in time into another oval or circular bit of experience like the first. The following reports are typical:

H (C 100 M) The hair touched lightly and began moving at once. As it moved it pressed more lightly and almost lifted off. Then, as it moved on, it pressed harder, and came down fairly lightly at the end. It moved faster at the beginning than it did in the middle.

H (C 100 P) The process began limited in extent. It increased in one direction to fairly extended, with slight contraction ending in a little spread of extent. It began as neutral pressure, becoming increasingly like contact until it was almost pure contact, with a rapid shift to pure neutral pressure. It was fairly weak, diminishing in intensity during the extent of the process, and becoming more intense at the end. The whole was very short.

The next type is much like the dumb-bell pattern, save that the movement does not start from the center of the first touch, but rather begins at the edge. In 'process' the first impression is described as static. Then there follows a growth from the edge.

H (C 100 M) A hair touched and rested; and then something started to move from the edge of the first touch and moved a little way, rested, and lifted off.

H (C 100 P) The process was limited and static for a bit; then growth began from the edge and became fairly extended. At first it was a dull neutral pressure, quickly shifting to a brighter pressure, and becoming neutral at the end. It was fairly weak, and dropped to weak. It was of short duration.

D (C 100 P) The process began as a contact fused with a wiry prick, immediately followed by a vague, diffuse, large pressure sensation localized differently.

In a third type the touches at beginning and end are of the same size as the moving touch between. There is no narrowing during the movement. In 'process' the terminals are marked by differences in quality and intensity, but not by a spread of extent. The first may be a pressure rather intense, merging into a spreading that is less intense, but of continuous extent, and ending in another intense pressure of the same extent.

W (C 100 M) A touch moved smoothly across my arm. It pressed harder at the beginning and ending than it pressed in the middle of its course. It was the same breadth all the way.

W (C 100 P) The process began, limited in extent, and spread in time, becoming weak during the spread but not contracting, and increasing in intensity as it became more extended. It began as good contact, and remained contact throughout. There was no change in extent at the terminals. The whole was short.

D (C 100 P) The process was neutral pressure, the area of which seemed to expand to another neutral pressure.

B (C 100 P) The process was a contact changing in intensity along a line.

The *O*'s describe the extension of the process in various other ways. It is called a 'flowing,' an 'extending in time,' a 'diffusing in time.' At first the word 'flow' was frequently used, but during the later reports it does not appear. Two *O*'s have said that 'flow' does not describe truly the depth of the sensation. Even when the intensity is weak, the growth seems to have the feel of something deeper than 'flow.' 'Ooze' has sometimes been used. H usually described the process as 'growth;' B and W used the term 'spread' most frequently; D spoke of 'extension and diffusion,' 'sensory continuum in time,' 'progression in time.'

With cutaneous stimuli the terminals, with few exceptions, are contact or neutral pressure. The same terms usually describe the subcutaneous experience; occasionally this is called 'drag' in the reports of H and W. In a few cases the subcutaneous stimuli produced a 'thicker' feel in the spread than did the cutaneous. In nearly all cases, except

those just mentioned, the reports for the two stimuli are exactly alike.

(2) *Full Movement in an Arc.*—Occasionally the *O*'s reported a full movement in the shape of an arc. The first touch became larger in some one direction, and at the coming of the second it seemed to be pulled round to that position. In 'process' this type is described as a pressure becoming extended irregularly, and spreading around one side to another impression.

D (C 75 M) A touch went around in an arc to a new position.
B (C 100 M) The hair moved on my arm in the form of an arc, and rested in another place.
H (C 100 P) The process began limited and spread in extent out around one side, becoming narrower and ending in a slightly greater extent. It was neutral pressure, then contact with a shift to neutral pressure. It was fairly weak, decreasing in intensity during the extent, and increasing to fairly weak at the end. It was of short duration.
B (C 100 P) A contact diffused in a half circle and fused with another contact.

No *O* reported the arc movement more than five times in all the experiments performed. It occurred only when full movements were reported. Unimembral and bimembral movements did not take the arc form.

(3) *Bimembral Movement.*—In the bimembral movement the stimuli are felt as two touches which move, but which have a spatial and temporal interval between them. In nearly all cases *a* moves toward *b*, and *b* moves away from *a* to a resting place. Occasionally *b* touches and then moves on and off without resting. In 'process' the experience is described as two pressures or contacts, separated spatially and temporally, both diffusing in time.

B (C 500 M) A hair touched me and moved a bit. It lifted off, and came down moving into a new place.
H (C 100 P) The first process began very limited and grew in extent to slightly extended. It was a neutral pressure quality fading out, and it was very short. The second process was limited and shrank in time to very limited. It was neutral pressure with a hint of contact at the beginning, and it was weak and short.
D (C 100 P) Two neutral pressures occurred successively in time and were localized differently in space. The first became diffused in time, and the second likewise.

(4) *Unimembral Movement.*—In the unimembral movement, sometimes the first stimulus moved and the second was stationary, but more often the second was the moving member. Stimulus *a* touched and was gone; *b* touched while moving away from *a* to a new position. In 'process' one of the impressions was said to spread or extend in time.

H (C 100 M) A hair touched me fairly lightly and lifted off. It touched again in another place, moving a short distance. It rested and lifted off.

W (C 100 P) First there was a contact limited and very weak. Near it in space was a contact spreading in time to a larger extent and becoming more intense during the spread.

H (C 100 P) The process began limited, and grew slightly in extent; it was dull neutral pressure becoming pure pressure in the extent. It was fairly weak, with the intensity dropping off. It was very short. The second process was very limited neutral pressure, and was fairly weak and short.

There were other reports more rarely given. Sometimes only one stimulus was felt, and it moved to a stopping place, or began as static and moved off. In 'process' such experiences were called "a spreading contact growing more extended and more intense as it spread," or "a contact which spread and faded out."

(5) *Intramembral Movement.*—The intramembral movement is "the feeling of movement as if the hair were held in an unsteady hand," or "a wiggling of the hair against the skin." In 'process' the experience is described as "a slight shift of the intensive pattern in time."

D (C 250 M) There were two touches successive in time and localized differently in space. The first quivered as if held in an unsteady hand.

B (C 500 P) There were two contacts differently localized and successive in time. The second had changes of intensity in time; otherwise it was just two.

W (C 1000 P) The first process was a contact which fluctuated in intensity in the touched area. The second process was pure contact, very limited and short.

H (C 100 P) The first process was very limited and rather a brightish pressure of moderate intensity and very short. The second process was a fairly limited neutral pressure quality. There was a shift in time of the intensive patterns from moderate to fairly weak. The whole was short.

(6) *Intramembral plus Unimembral Movement.*—In the manual experiments and the first series of the mechanical stimulations there were reported some cases of combined perceptions of intramembral and unimembral movement. Sometimes one stimulus gave the perception of intramembral movement, and the other that of unimembral movement. Occasionally one stimulus would begin its movement as intramembral, and then extend into unimembral movement. These reports do not appear in the last series, in which the reports of unimembral and intramembral movements became uniform and clear-cut, with no hint of confusion or addition.

(7) *Phi Movement.*—The phi movement occurs infrequently. A typical 'meaning' report is: "It felt as if a moving some-

thing flicked against my arm." In this perception we do not have the feeling of two touches, or of one touch moving to a new position. In 'process' there were no distinct terminal experiences; the pressure is called "a weak, spreading contact, a bit more intense in its middle portion." Most of the pure phi-reports occurred in the manual experiments, and came early in the series.

(8) *Backward Movement.*—In the manual experiments and in the first series with the mechanical stimulations there were a few reports of unimembral and bimembral movement in which the stimulus seemed to move backward. That is, one impression was felt; and the second, instead of moving away from it to a new position, would be felt some distance away moving toward the first. H and W reported this perception three or four times in the manual experiments, but not afterwards. B reported it twice in the manual experiments; four times in Series I with the mechanical stimulations, and not at all in Series II. D reported backward movement three times in the manual experiments; in Series I of the mechanical stimulations he gave no such reports; in Series II he reported it 24 times (6.25% of all the reports in that series).[9]

(9) *No Movement: Two Points Distinct.*—In nearly all cases in which no-movement was reported, the perception was of two points touched successively in time and having spatial separation. Sometimes the one impression was more diffuse than the other, or differed from it slightly in quality; usually the two were reported as alike. This type of perception occurred in all experiments with intervals above 50σ.

(10) *No Movement: Conjunctive.*—A report made frequently with the 25σ intervals belongs to the no-movement group, though it indicates something more than merely two touches which did not move. The second stimulation was added to the first, or placed beside it. Sometimes the second grew larger after it had appeared, and again it came as a diffuse, ill-defined touch. In 'process' one contact or pressure had added to it another, and there was little separation of the two in space and time.

D (C 25 M) There were two light touches which came separately, but whose areas overlapped.

H (C 25 P) The first process was very limited. It was a weak contact and very short. Beside it came another process of pressure

[9] D's observation of backward movement evidently became a matter of habituation. Very occasionally in this series he reported triple pressure; as, for instance, pressure at *a* followed by a pressure at *b* which moved back toward *a* and then ended with increased intensity.

quality, with a fringe having in it a hint of contact. It was of very weak intensity and very short.

H (C 25 P) The process was very limited and was added to. It became fairly limited in one dimension. It was of neutral pressure quality with a fringe of contacty pressure. It was fairly weak. The whole process was fairly extended and fairly weak.

(11) *No Movement: Superpositive.*—Occasionally the two stimulations seemed to be successive in time but to fall upon the same spot.

W (C 25 M) There were two touches, first one and then another beside it covering it. The two were almost successive in time.

H (C 25 P) The first process was very limited, and while it was still present another limited process covered it. The second was more extended, but there was perfect fusion of the two. Both were good neutral pressure quality, of weak intensity. The first was very, very short. The second was slightly longer.

D (C 25 P) The first process seemed obscured by the second. I was conscious of the first, but it was absorbed by the second, which was big and which gradually became bigger.

It will be noted that whereas B, H and W have a large number of reports falling into the no-movement group in the 25σ interval, D has but few.[10]

Distance of Movement

Under the 'process' instruction the *O*'s never reported how far the stimulus moved in full movement, or how far apart were the members in part movement. In 'meaning' the perceptive distance in the larger intervals, as occasionally reported, was always greater than it was in reality, and varied according to the interval. With the 1000σ interval it was reported as 1.5 to 2 cm. As the intervals shortened, the distance decreased to 4 or 5 mm. at the 100σ interval, and at the 25σ interval the stimulations were side by side.

Rate of Movement

Rate of movement, like distance, was reported only under the 'meaning' set. Sometimes during the manual experiments the *O*'s said that the movement went "quick as a flash" or "rapidly." Sometimes in the full movement reports one part of the movement was said to move more quickly than another. In bimembral movements, the *O*'s occasionally said that "the second went quicker than the first." Aside from instances where one part of a movement could be compared with another in the same perception, the *O* was uncertain of the rate, and hesitated to report it. During the mechanical

[10] See footnote 9.

stimulations the reports of rate dropped out. If questioned about it, the *O*'s said: "I am not sure," or "I can't report on it."

Stimulations of Long and Short Duration

After the series with the duration of the stimulus at 150σ, four other series (2C and 2S) of 24 experiments each were performed with H and W. In these series the 75 and 100 intervals were used, and the durations were 75 and 200σ. No full movements were reported by W with duration at 200σ; H gave such reports in 6M and 4P at C 100. With duration at 75σ with C 100, H reported full movement in 14M and 17P, and W in 14M and 15P. These reports are almost the same in number and content as those with the duration at 150σ. With C 75, H had no full movements and W had 5M and 8P. With S 75 neither H nor W reported full movement. With S 100, H had 8M and 2P full movements, and W had 8M and 8P. Since the intervals longer and shorter than 150 proved to be not so good as 150, and in only one case compared favorably with it, no farther experiments were performed with them.

Experiments Upon Non-Adjacent Spots

A short series of 24 experiments with each stimulus was performed upon non-adjacent spots. The spots *a-c* and *a'-c'* were used. H and W again served as *O*'s. The stimulations were made with the 75 and 100σ intervals. The duration was 150σ. H reported no movement during any of the experiments. W in S 75 had 8M and 12P unimembral movements. The movement always occurred with the second member. With C 100, W reported 12M and 14P unimembral movements, also at the second member. The movements were very short. There was just a hint that the second stimulus slid a very short distance into place. In 'process' the second stimulus had a very slight diffusion in time.

Cutaneous Versus Visual Movement

Dimmick under his best conditions obtained full movement with 'process' instructions in 90 to 93% of his reports, and with 'meaning' instructions in 81 to 91%. We under the most favorable conditions obtained on the average with C only 13.75 (57%) M-reports and 14.25 (59%) P-reports out of a possible 24; and with S, 16 (67%) M and 14.75 (61%) P. It seems from a comparison of these figures that the cutaneous perception of movement is less fundamental and

compulsory than the visual. There was, it is true, a difference in the plan of the two investigations, since Dimmick's stimulus *a* in his regular series always bore a fixed spatial relation to his stimulus *b;* whereas the spatial relations of the spots stimulated by us varied from group to group. Our stimulus *b* might lie above or below *a,* to right or to left of *a.* It is difficult to say how far this difference influenced the results; but it seems from what indications we have that the influence was slight. (1) A special C-series made with H, in which the same two spots *a-b* were stimulated in the same order in successive observations to the point of exhaustion, yielded no increased percentage of full movements. (2) The conditions of our mechanical stimulation approximated those of Dimmick's experiments. After the first two or three stimulations of two spots at the beginning of a group of twelve experiments, *O* knew when the second stimulation came that it was in the same place as before, and so learned to expect it at that place. H, who observed in Dimmick's work, said: "I was not conscious of expecting the second stimulation in the place where it came, but when it did come I had the feeling that it was where it ought to be and where it had been before." H further remarked that the expectancy was "the same sort of thing as in Dimmick's experiments." W, who also observed with Dimmick, verifies these reports.

Only one *O,* B, reported associated visual images, and she only in the early stages of practice. H and W declared that visual images did not appear; and D when questioned said that he had them occasionally, but that they were never a determining factor in his perceptions.

The aberrant types of perception, the arc-movement and the backward movement, seem to be conditioned upon some directional emphasis within the tactual spread. Ordinarily the spread of sensation is roughly circular or oval. If, however, some lateral segment of *a*'s spread is unusually intensive, the arc movement necessarily follows; and if *a*'s spread is uniformly weak, and *b*'s is strongest over a segment that points toward *a,* the perception of backward movement follows. We have no means of knowing how these local emphases arise, but the *O*'s reports show that they appeared and formed the basis of judgment. There is, of course, nothing parallel in Dimmick's results.[11]

[11] Dimmick tried to get backward movement by artificial emphasis and failed: *op. cit.,* 331.

Conclusions

(1) We have succeeded in synthetizing the perception of cutaneous movement, from two separate and successive stimulations, under conditions that parallel Wertheimer's synthesis of visual movement.

(2) The optimal conditions for the arousal of the perception are: with cutaneous stimuli, a duration of 150^{σ} and an interval of 100^{σ}; with stimuli that also affect the subcutaneous organs, a duration of 150^{σ} and an interval of 75^{σ}.

(3) (*a*) The most important conditions of the perception, under our conditions, are the interval elapsing between the successive stimuli and the adjacency of the spots stimulated. (*b*) The duration of 150^{σ} is best for arousing the perception of full movement; the number of full movements aroused with longer times is much lower. The same thing is true also of the duration of 75^{σ} except in one instance, namely C 100, where the number of full movements aroused compared favorably with those reported when the duration was 150^{σ}. (*c*) The stronger of our two intensities, the 'subcutaneous' stimulus, yields a slightly larger percentage of full movements with its best interval, 75^{σ}, than does the cutaneous stimulus at its best interval, 100^{σ}.

(4) Whereas Dimmick was able to secure the perception of visual movement, under optimal conditions, in practically 100% of his trials, we found that the perception of cutaneous movement appeared, under the same conditions, in only 57 to 67% of our observations. Since, so far as we can discover, there is nothing in the arrangement of the two experiments that accounts for this difference of result, we are forced to the conclusion that the cutaneous perception is less fundamental and compulsory (in Dimmick's sense) than the corresponding visual perception.

(5) Support for this view is found in a comparison of the existential correlates of the two perceptions. Dimmick's grey flash is an integration of quality with time; space is not involved. The existential correlate of the cutaneous perception appears, on the other hand, to be an integration of quality, time and cutaneous extent. While Dimmick's *O*'s reported a curtain or film of shimmering, liquid, live grey, our *O*'s (in part the same as Dimmick's) report a pressure diffusing, growing, extending, in time. The integration appears to be of a higher order, and therefore less stable and inevitable.

(6) We regard it as entirely premature to theorise from the results of Wertheimer and Dimmick in vision and from our own results in touch to 'the' perception of visual or cutaneous movement. It may very well be that the singular number must be replaced in this and similar connections by the plural. 'Movement' is, after all, a gross meaning that may be carried by several existential correlates; or, to put the same thing in other words, an organism whose outfit of sense-organs is as complex as our own may be adequate to the 'perception of movement' by way of several different primary integrations.